
Weather Impact on UAS Operations

Ceiling & Visibility

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(presented by Jim Evans)

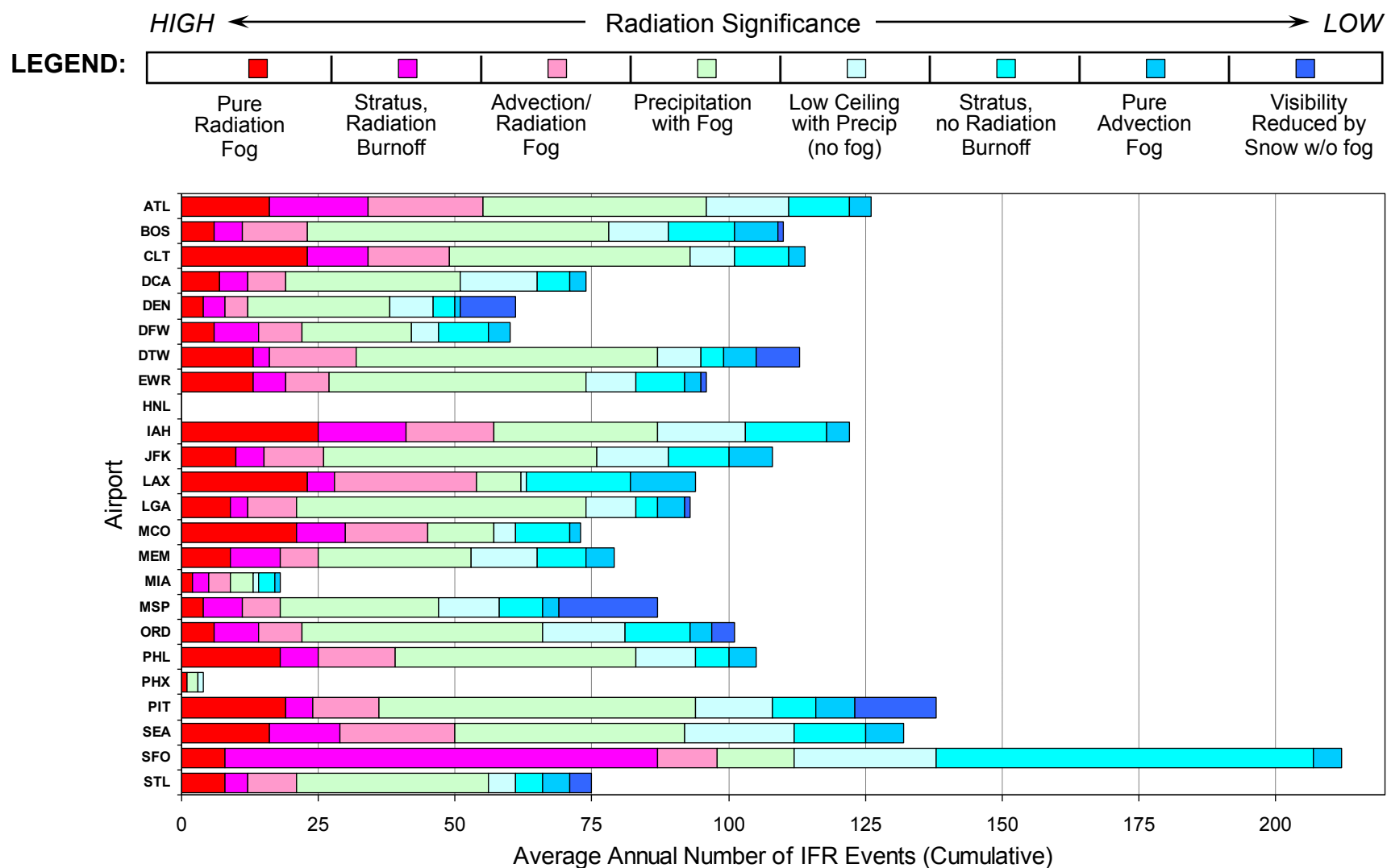
20 July 2016

NASA UAS Weather Workshop



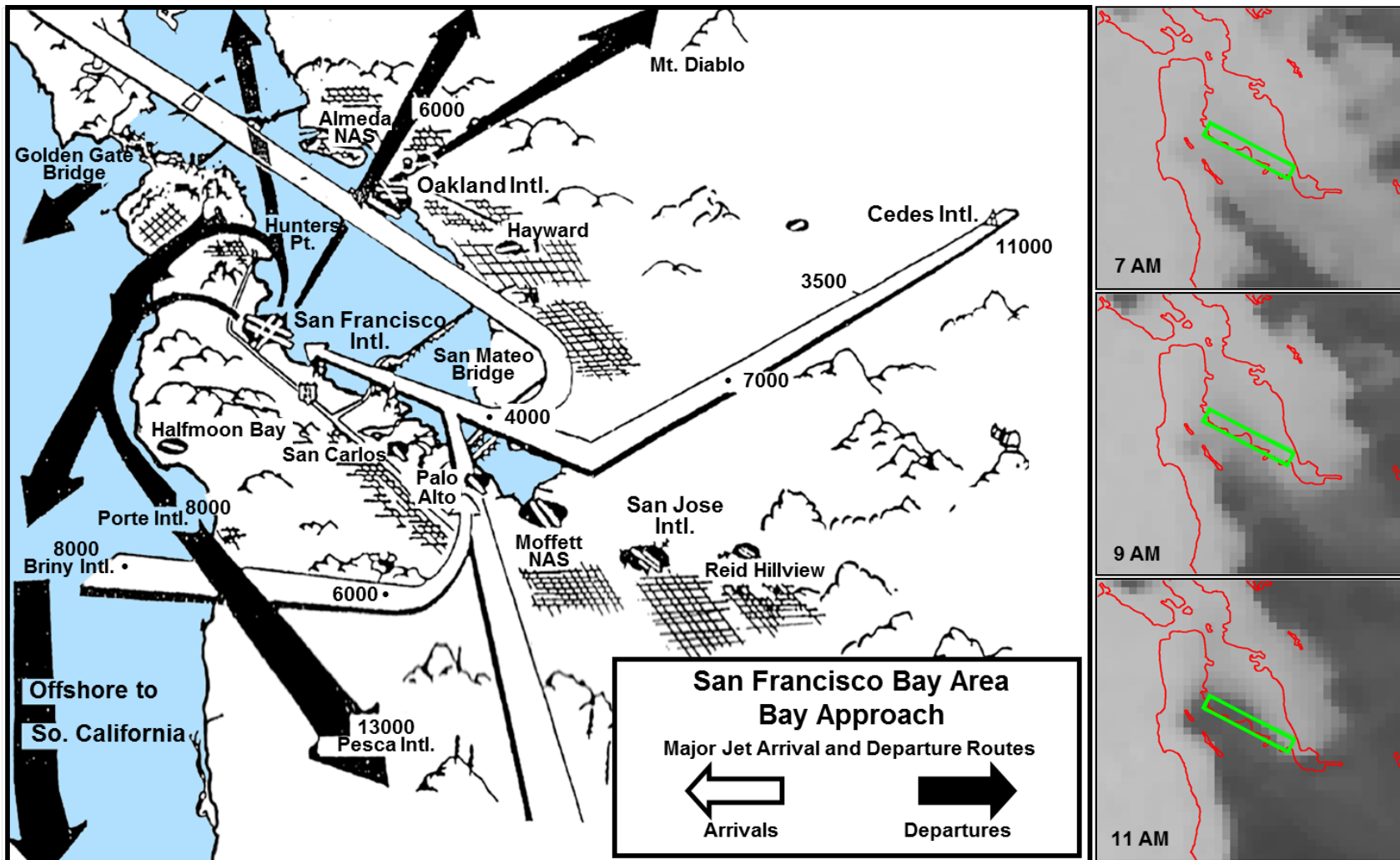


Annual Number of IMC Events, by Primary Cause





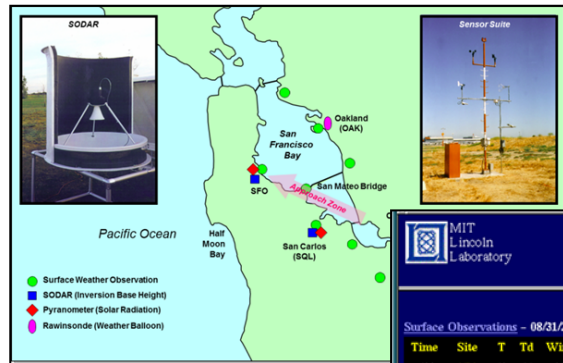
Stratus ceiling impact on SFO Approach



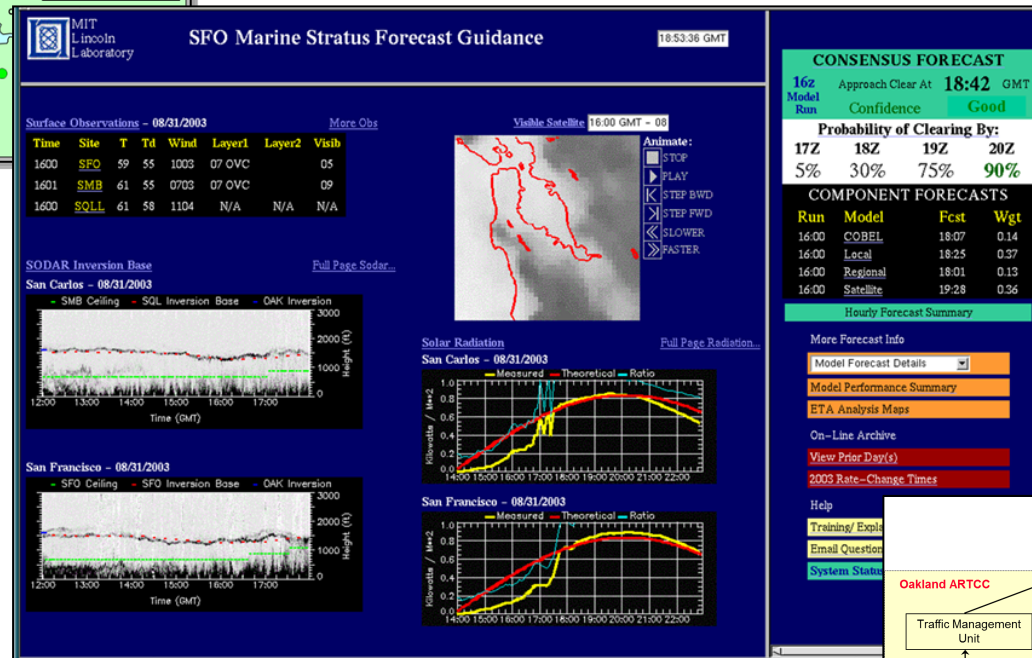


R&D Forecast Decision Tool Solution

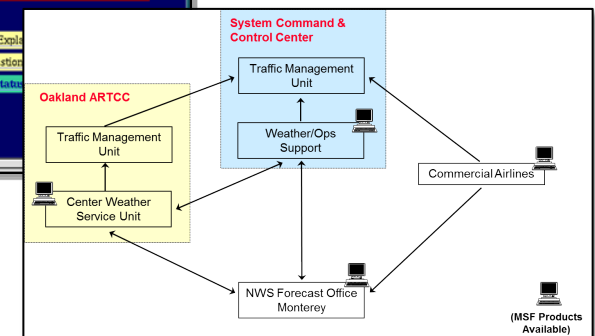
Sensor Suite



Probabilistic Forecast Guidance



Shared Amongst
Decision Makers



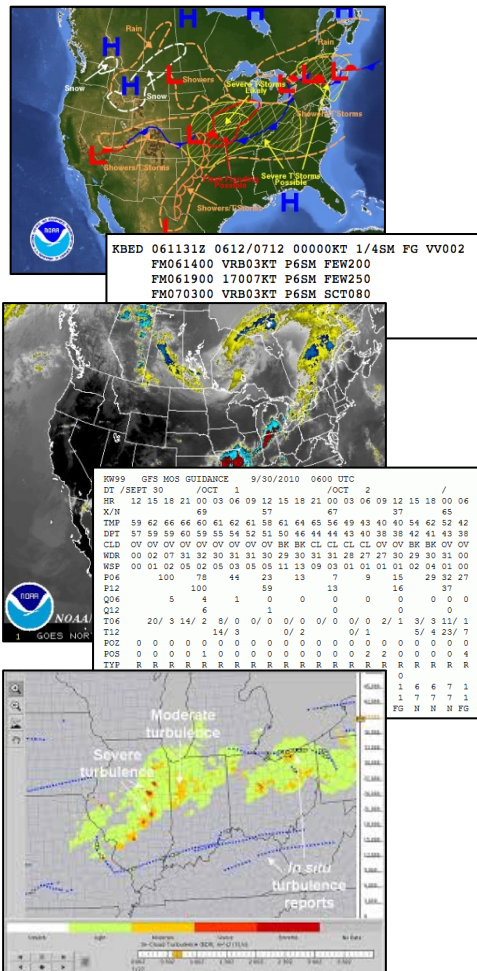


Outline

- **UAS weather impact and requirements**
- **C&V impact on small UAS**
- **C&V analysis and forecasting resources**
- **Opportunities for improvement**
- **Summary**



Weather impact on UAS



Impact on UAS mission

- Vehicle performance
- Mission objectives

Impact on mission options

- Proceed as planned
- Modify timing/route
- Cancel / re-schedule




Investigate weather information requirements for UAS operations

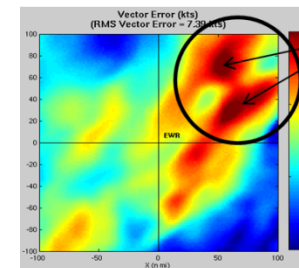
Classify broad range of UAS missions and vehicle types by commonly reported weather needs



Mission Class		UAS Class				
	Use Case	1	2	3	4	5
Low Altitude/Endurance	Single and multiple missions Autonomous navigation Payload management					
Low Altitude/Endurance	Power Production/operation Power Distribution/operation Autonomous flight applications Signal and timing Autonomous landing Data processing					
Mid Altitude/Endurance	Inventory management Data processing					
High Altitude/Endurance	Communication/mission planning Autonomous navigation Autonomous flight applications Signal and timing Autonomous landing Data processing					
High Altitude/Endurance	Power Production/operation Power Distribution/operation Autonomous flight applications Signal and timing Autonomous landing Data processing					
High Altitude/Endurance	Inventory management Data processing					

Prioritize use cases and investigate ability of current weather products to meet operator needs

 Federal
Aviation
Administration



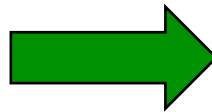




Weather requirements survey

Stakeholders queried about specific weather elements

Please provide the **significance** of each of the below weather condition to the feasibility of your operation. If it is not applicable mark (N/A):

Surface Wind Direction / Crosswind Component	<input checked="" type="radio"/> N/A	<input type="radio"/> Not at all Significant	<input type="radio"/> Neutral	<input type="radio"/> Very Significant
Surface Wind Speed	<input type="radio"/> N/A	<input type="radio"/> Not at all Significant	<input type="radio"/> Neutral	<input type="radio"/> Very Significant
Surface Wind Gust Speed	<input type="radio"/> N/A	<input type="radio"/> Not at all Significant	<input type="radio"/> Neutral	<input type="radio"/> Very Significant
Winds Aloft	<input type="radio"/> N/A	<input type="radio"/> Not at all Significant	<input type="radio"/> Neutral	<input type="radio"/> Very Significant
Temperature	<input type="radio"/> N/A	<input type="radio"/> Not at all Significant	<input type="radio"/> Neutral	<input type="radio"/> Very Significant
Barometric Pressure	<input type="radio"/> N/A	<input type="radio"/> Not at all Significant	<input type="radio"/> Neutral	<input type="radio"/> Very Significant
Precipitation	<input type="radio"/> N/A	<input type="radio"/> Not at all Significant	<input type="radio"/> Neutral	<input type="radio"/> Very Significant
Thunderstorms / Lightning	<input type="radio"/> N/A	<input type="radio"/> Not at all Significant	<input type="radio"/> Neutral	<input type="radio"/> Very Significant
Cloud Cover / Ceiling	<input type="radio"/> N/A	<input type="radio"/> Not at all Significant	<input type="radio"/> Neutral	<input type="radio"/> Very Significant
Horizontal Visibility / Fog	<input type="radio"/> N/A	<input type="radio"/> Not at all Significant	<input type="radio"/> Neutral	<input type="radio"/> Very Significant
Turbulence	<input type="radio"/> N/A	<input type="radio"/> Not at all Significant	<input type="radio"/> Neutral	<input type="radio"/> Very Significant
Icing	<input type="radio"/> N/A	<input type="radio"/> Not at all Significant	<input type="radio"/> Neutral	<input type="radio"/> Very Significant
Other (write in condition)	<input type="radio"/> N/A	<input type="radio"/> Not at all Significant	<input type="radio"/> Neutral	<input type="radio"/> Very Significant



- Thunder/Lightning [6.8]*
- Precipitation [6.7]
- Surface Wind Speed [6.4]
- Surface Wind Gust [6.4]
- Visibility/Fog [6.0] 
- Cloud/Ceiling [5.4] 
- Icing [5.4]
- Winds Aloft [4.8]
- Turbulence [4.3]
- Temperature [4.1]
- Surface Wind Direction [3.9]
- Pressure [2.4]

** Importance on 1-7 scale*

90 small UAS surveys received



Small UAS rules related to visibility

- **Governed by FAA small UAS Rule (Part 107)**
 - Adopted June 21, 2016
- **Visual line-of-sight (VLOS) only**
- **Daylight operations only**
- **Minimum weather visibility of 3 miles from control station**
 - Implied cloud ceiling of 400 feet in area of operations
- **Maximum altitude of 400 feet AGL or, if higher than 400 feet AGL, remain within 400 feet of a structure**





Obstructions to visibility

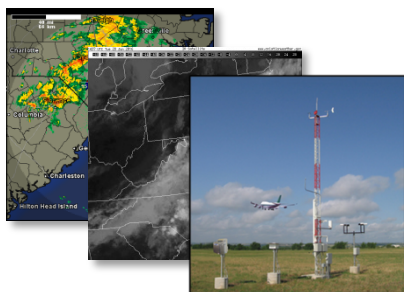
- **Fog**
 - Formed by cooling
 - Radiation, advection, upslope
 - Formed by evaporation
 - e.g. associated with precipitation
- **Cloud (elevated fog)**
 - Transient synoptic scale systems
 - Convective systems
- **Precipitation**
 - Highly variable with water phase
 - Snow, rain, ice pellets, etc.
- **Haze, smoke, dust, volcanic ash**



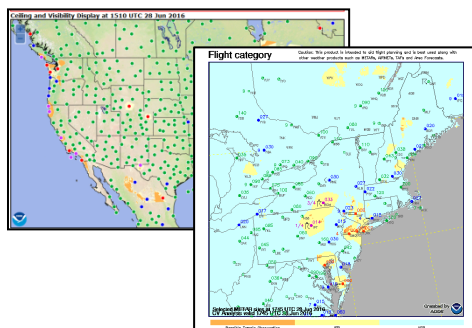


Sources of C&V information

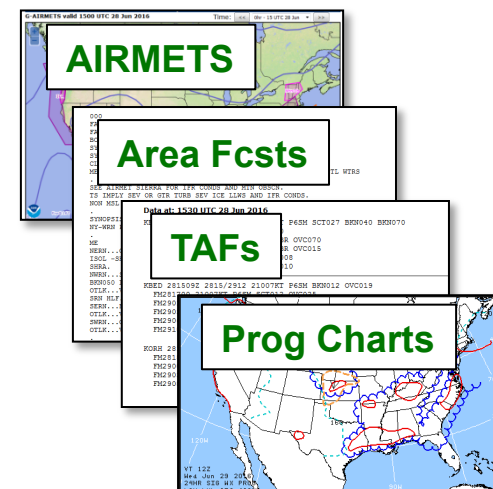
Observation Data



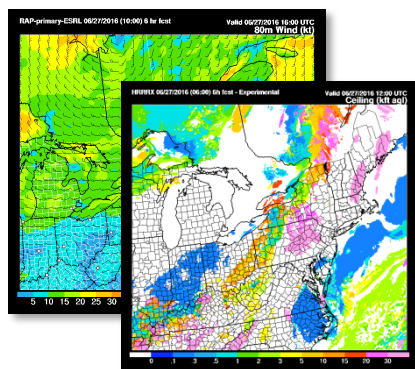
Derived Analysis



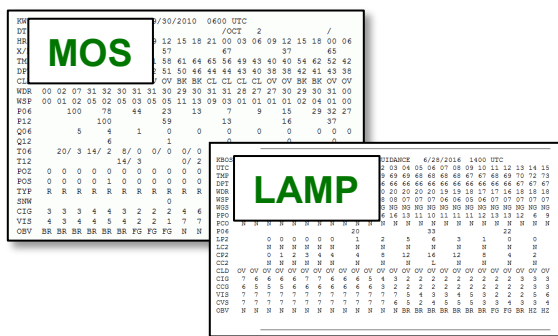
End Products



NWP Models



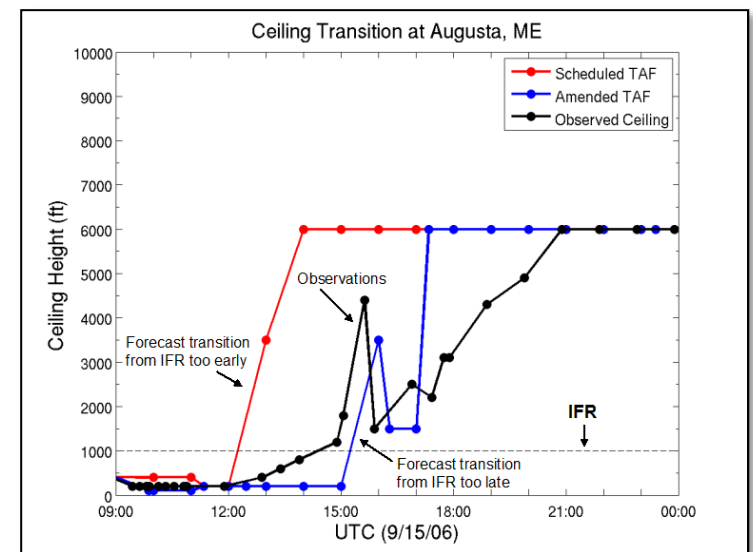
Statistical Guidance





Opportunities for improvement

- **SURVEY:** Observations and forecasts need to be more specific to location of UAS operations, which tend to **NOT** be near airports
- **SURVEY:** Forecasting start/end of C&V events is a challenge, but improvements would be beneficial
- For UAS aspect, provide a probabilistic forecast that directly addresses the operation
 - Vehicle and location
 - Specified operational thresholds
 - Prescribed time window



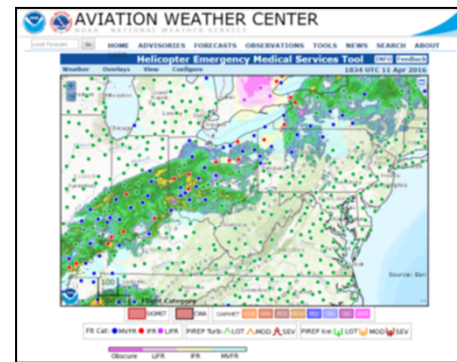
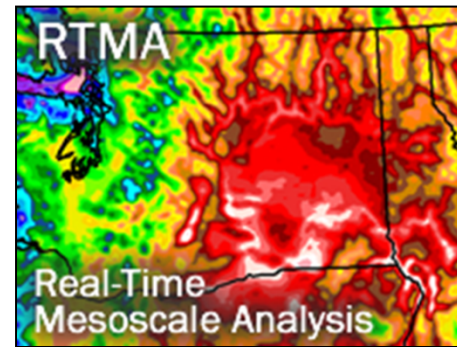
TAF “chasing” the observations



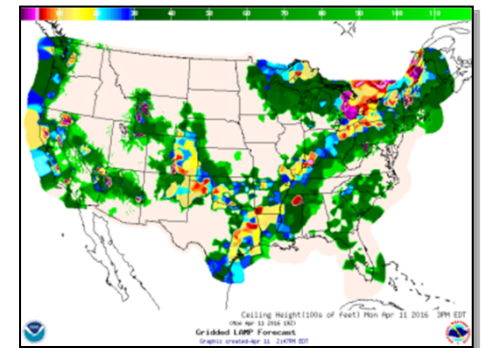
AWRP R&D: CONUS C&V

Participants: NOAA labs (EMC, MDL, AWC, ESRL), FAA

- **Overall Goal:** Improve analysis and prediction models while increasing information frequency
- Improvements to C&V analysis in the form of the Real Time Mesoscale Analysis (RTMA)
- Improvements to 0-2 hour LAMP C&V forecasts
- Test techniques for forecasters to enhance automated products
- Integration of improvements into HEMS, TAFs, and Area Forecasts
- Provide national C&V grids for use in Aviation Digital Aviation Services



Helicopter Emergency Medical Services (HEMS)



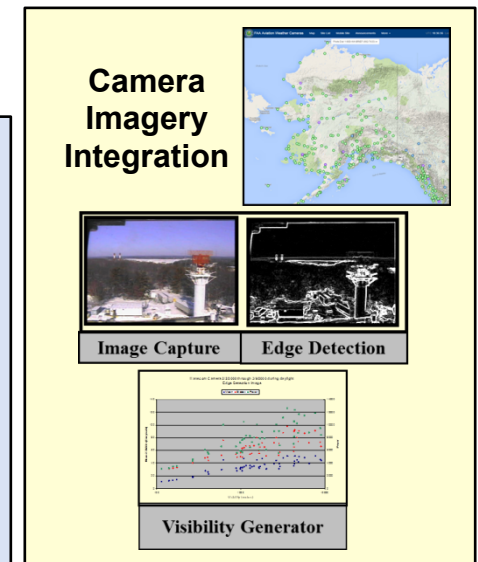
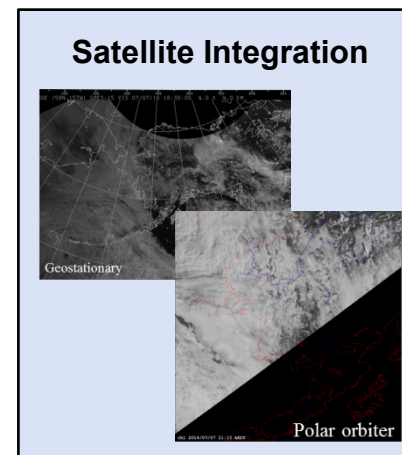
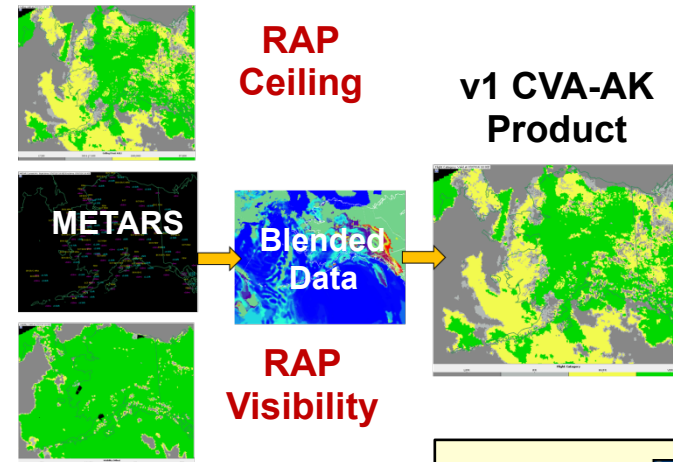
Graphical LAMP



AWRP R&D: Alaska C&V

Participants: Alaska Aviation Weather Unit, NCAR, MIT/LL

- **Overall Goal:** Data fusion techniques to blend multiple observations with NWP 1-hour C&V forecasts to yield a C & V analysis (CVA) product
- Version 1 CVA-AK product blends METAR C&V observations with RAP 1-hr forecast fields
- Version 2 integrates geostationary and polar orbiter satellite data
- Version 3: Integrates visibility information retrieved from FAA web cameras





Notional UAS Decision Support Tool Information Flow



Operator	John M. Smith	Launch Date	10/28/2015
User ID	CA25758	Launch Time	09:00 EDT (13:00 GMT)
Vehicle Type	DJI Phantom	End Date	10/28/2015
Vehicle ID	DJI-5181	End time	10:00 EDT (13:45 GMT)
		Launch Location	43.2055 N / 75.381 W
		Max Distance	1.0 nmi



Notional UAS Mission Decision Tool Concept

User identifies weather element thresholds:

User-Selected Weather Constraints

	Threshold	Units								
Wind Speed (0-50 ft AGL)	max	knots	7.	10	15	17	20	22	25	15.
Wind Speed (50-500 ft AGL)	max	knots	7.	10	12	15.	17	20	22	25
Precipitation	allowable		NO		YES					
Cloud Ceiling Height	min	ft AGL	0	100	200	300	400	500	1000	
Visibility, horizontal	min	nmi	0	1/4	1/2	3/4	1	2	3	5
Minimum temperature	min	deg C (F)	-30 (-22)		-20 (-4)		-10 (14)		0 (32)	
Maximum temperature	max	deg C (F)	35 (95)		40 (104)		45 (113)		50 (122)	
Turbulence	allowable		None		Light		Moderate		Severe	
Icing	allowable		None		Light		Moderate		Severe	

Translation converts source forecast to mission impact:

	Threshold	Fcst	Prob*	Fcst	Prob*	Fcst	Prob*	Fcst	Prob*		Probability*
Wind Speed (0-50 ft)	10.0 kts	4	98%	6	95%	6	95%	7	90%		95%
Wind Speed (50-500 ft)	12.5 kts	7	97%	8	93%	8	93%	10	85%		93%
Precipitation	No	None	99%	None	99%	None	99%	None	99%		99%
Cloud Ceiling Height	500 feet	None	99%	None	99%	None	99%	2500	90%		99%
Visibility, horizontal	1 nmi	10 mi	99%	10 mi	99%	10 mi	99%	3 mi	90%		99%
Minimum temperature	-10 (14)	42 F	99%	44 F	99%	47 F	99%	50 F	99%		99%
Maximum temperature	40 (104)	42 F	99%	44 F	99%	47 F	99%	50 F	99%		99%
Turbulence	Light	None	99%	None	99%	None	99%	Light	85%		99%
Icing	None	None	99%	None	99%	None	99%	None	99%		99%
All conditions	None	None	96%	None	92%	None	92%	None	75%		91%

* Probability that conditions meet acceptable criteria



Summary

- **Primary impact of C&V on UAS is Line-of-Sight restriction with 3-mile horizontal visibility requirement**
 - **Implied cloud ceiling minimum of 500 feet**
- **Variety of C&V physical forcing mechanisms make it a difficult forecasting challenge**
- **Forecasts currently rely on a host of observations, NWP models, statistical guidance, and end user products**
- **Areas for improvement**
 - **Localization of forecast to non-airport UAS operational site**
 - **Improvement to start/stop times of impacting C&V events**
 - **Use of non FAA cameras (DOT, local government, security) could potentially be very useful in metropolitan areas**
- **Product improvements in development**
- **Need to incorporate ceiling and visibility into a weather-aware mission planning Decision Support Tool for UAS applications**